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Routing Design Issues in Heterogeneous Wireless Sensor Network

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ABSTRACT

WSN has important applications such as habitat monitoring, structural health monitoring, target tracking in military and many more. This has evolved due to availability of sensors that are cheaper and intelligent but these are having battery support. So, one of the major issues in WSN is maximization of network life. Heterogeneous WSNs have the potential to improve network lifetime and also provide higher quality networking and system services than the homogeneous WSN. Routing is the main concern of energy consumption in WSN. Previous research shows that performance of the network can be improve significantly using protocol of hierarchical HWSN. However, the appropriateness of a particular routing protocol mainly depends on the capabilities of the nodes and on the application requirements. This study presents different aspects of Heterogeneous Wireless Sensor network and design issues for routing in heterogeneous environment. Different perspectives from different authors regarding energy efficiency based on resource heterogeneity for heterogeneous wireless sensor networks have been presented.

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1. INTRODUCTION

Due to many real life applications of the Wireless Sensor Networks (WSNs) like health monitoring, aircrafts, disaster management, defense security, researchers gives attentions towards WSN. As we know that homogeneous Wireless Sensor Network are not suitable for real life application because rechargeable battery support and very limited and less energy resources are available that is why researchers tries to enhancing or increasing the lifetime of Wireless Sensor Networks. But in case of heterogeneous wireless sensor network, by using different types of sensor which having different capabilities can prolong the network life time [1]. To design energy efficient protocols in HWSN, most of the researchers considered routing is the main concern. In routing, clustering is the main method for heterogeneous WSN. Clustering improves the scalability and extends the lifetime of WSNs.

In WSN sensors are battery supported and mostly unattended, due to these reasons minimization of energy consumption must be taken into consideration to prolong the network lifetime from all aspects.

The contribution of the paper is organized as follows: Section 2 gives overview of heterogeneous WSN. Section 3 discusses classification of heterogeneous WSN. Section 4 focuses on performance of heterogeneous sensor network. Section 5 presents design issues of routing in heterogeneous wireless sensor network Section 6 classifies and compares the proposed routing methods in heterogeneous wireless network, Section 7 conclude this paper.

2. OVERVIEW OF HETEROGENEOUS WIRELESS SENSOR NETWORK

A heterogeneous wireless sensor network (HWSN) is the network of sensors having wireless link with dissimilar communication range for example, as shown in Figure 1 we can have different communication technology like IEEE 802.3, IEEE 802.11 and ZigBee. Similarly we can have different node with different sensing range or different computational capabilities or we can construct WSN in which, nodes are equipped with different sensors to provide various sensing services. If there are two types of sensors one is high end, which is having high process throughput and longer communication or sensing range and low end sensors having low process throughput and short communication or sensing range then while deployment if we use mixer of these two types we can achieve balance between cost and performance of WSN.

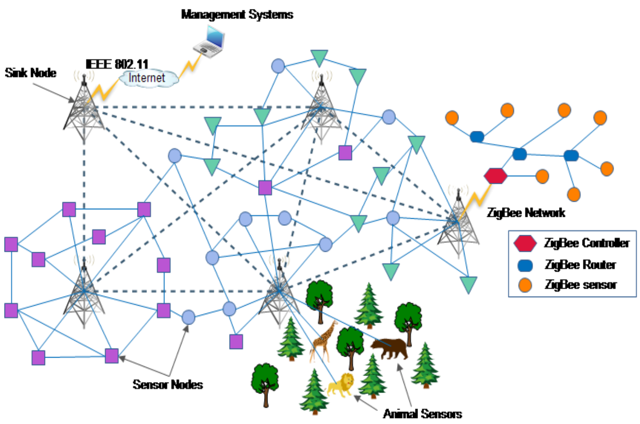

Figure 1. Heterogeneous Wireless Sensor Networks [2]

In a distributed HWSN, different parts of HWSN may adapt different network configurations as shown in Figure 1. Heterogeneous WSN topology control and deployment is more complex as compared to homogeneous WSN .But then also heterogeneous WSN is more popular than homogeneous because lifetime of WSN is very important , which can improved using HWSN

Recently, heterogeneous sensor network are widely used in multimedia application like environment monitoring of nature, online monitoring of high voltage transmission line [3] etc. A notable feature of this kind of network is that it has small data volume scalar sensors such as temperature, humidity, acceleration sensors etc, as well as large data volume vector sensors such as image, voice sensors etc. With large data to transmit, conventional low rate wireless sensor network technology (such as Zigbee) can't meet the demand of data transmission that is why heterogeneity in communication technology is introduced which supports all types of data.

For efficient use of resources, WSNs are typically formed in hierarchical manner. According to survey heterogeneous WSNs have the potential to provide higher quality networking and system services than the homogeneous counterparts .

3. CLASSIFICATION OF HETEROGENEOUS WIRELESS SENSOR NETWORK

The heterogeneous wireless sensor network can be divided into the following types based on sensing capability, computing power, transmission link ability, communication ability and energy.

3.1. Link heterogeneity

In this type of network some nodes are high-speed network link node, such as network interface having 802.3 Ethernet or some nodes having 802.11 WLAN as a network interface. In other words the heterogeneous node has long distance network transceiver and high bandwidth than the normal node. Due to Link heterogeneity a more reliable data transmission is possible because high speed network link or high bandwidth provides less chance of data loss during transmission.

Average number of hops that data packets travel from each sensor to the sink is reduces using Link heterogeneity. These high speed links provide a highway bypass throughout the network, and also increasing the end-to-end delivery rate and decreasing energy consumption [4].

3.2. Energy Heterogeneity

It means that the network contains energy heterogeneous nodes, some are line powered or its battery is replaceable. Energy heterogeneous feature is universal, because different types of transfer sensor nodes equipped with different initial energy, Even if the sensor network composed of the same type of sensor its node can’t be equal to use its energy, because of influence that the communications link temporary failure or terrain features and other random event. Sensor network will also show heterogeneous characteristics. In HWSN, a large number of nodes perform sensing which are inexpensive, while some nodes having more energy perform data filtering, fusion and transport. This leads to the research on heterogeneous networks where energy heterogeneous nodes are considered. The lifetime of network can be improved by energy heterogeneous nods in wireless sensor networks.

Computational heterogeneity and link heterogeneity consume more battery energy resource hence Energy heterogeneity is most important. Computational heterogeneity and link heterogeneity will bring negative impact to the sensor network if there is no energy heterogeneity [4].

3.3. Computational Heterogeneity

In this type of network some nodes are having a more rapid microprocessor or micro controller unit (MCU) and more storage space than normal node. Heterogeneous nodes with the powerful computational resources, complex data processing and more temporary data storage are possible.

3.4. Sensor Heterogeneity

It means network contains nodes having different perceptual range; perceptual range is mainly applied to sensor network node covering aspects of the research.

3.5. Communications Heterogeneity

It refers to the different communication range of sensor nodes, which is mainly used in network design and connectivity analysis. It is assumed that the communication range is two times the sensing range. Connectivity and coverage problems are based on limited communication and sensing range. The solution to these problems depends on how the sensors are positioned with respect to each others. So good sensor deployment algorithm maximizes the total area covered by sensors [5].

3.6. Deployment Heterogeneity

Deployment of nodes also introduces heterogeneity in the network, like Random, mobility model. In random model allows us to keep average number of nodes under a given threshold. Nodes are always deployed over a two dimensional plane. The number of sinks may be one or more depending on the specific scenario. Self-deployment and relocation of sensors can be achieved using mobility model, because sensors find their own position and placed themselves after initial sensor distribution [6]

3.7 Sensing heterogeneity

In sensing heterogeneous network, different sensors may sense different physical phenomena generating traffic that have different characteristics such as monitoring temperature, pressure, and humidity. Multiple traffic sources with different characteristics.

4. BENIFITS OF HETEROGENEITY ON PERFORMANCE OF WIRELESS SENSOR NETWORK

The effect of using few heterogeneous nodes in the WSN can bring the following benefits.

4.1. Prolonging Network Lifetime

In the heterogeneous WSN, the average energy required for forwarding a packet from the sensing nodes to the sink will be much less than the energy required consumed in homogeneous WSN. The Power consumption is reduced by decreasing the transmission power or by working over duty cycle and that is possible with communication and computational heterogeneity. Main lifetime limiting factor is limited energy supply and that can be minimized by energy heterogeneity. Different techniques such as clustering and data aggregation have already been proposed to improve energy consumption rate and network's lifetime. Clustering is a key technique where sensor nodes are organized into clusters for that energy heterogeneity is useful, which extends the lifetime of WSN. Details of clustering will discuss in section IV. If we use heterogeneity properly then the response of the network is increased three times and the network’s lifetime can be increased by five times.

4.2. Reliability Improvement of Data Transmission

Due to low reliability links each hop significantly lowers the end-to-end delivery rate. But with heterogeneous nodes; there will be fewer hops between sensing sensor nodes and the sink. So the heterogeneous WSN can achieve higher end-to-end delivery rate than the homogeneous WSN. The reliability is maintained by using energy heterogeneity because it will not let the node to die shortly and the computation heterogeneity is used to make the report fast [7].

4.3. Decreasing Latency of Data Transportation

Using some more rapid micro controller, Computational heterogeneity can decrease the processing latency in immediate nodes and using some high speed link, link heterogeneity can decrease the waiting time. Hence response time is decreased and less number of hops between sensor nodes and sink node also mean fewer forwarding latency. Using channel heterogeneity we can decrease the time at which the report is send or any event detection report.

5. EFFECTIVE NETWORK SERVICES PROVIDED BY HETEROGENEOUS WIRELESS NETWORK

In this section some of network services are focused which having high impact of heterogeneity

5.1. Coverage

To evaluate WSN’s effectiveness, determining sensor coverage for a designated area is very important. The coverage is defined as the probability that any target point in the sensed area is within the sensing range of any nearby sensors. Some applications such as target tracking may require a higher degree of coverage to track the target and other applications such as environmental monitoring can tolerate a lower degree of coverage. A higher degree of coverage requires multiple sensors monitoring the same location to produce more reliable results.

Due to heterogeneity nodes with better capability, namely longer sensing range and transmission range, high energy capacity can dramatically increase the network coverage and broadcast reachability and network lifetime also.

On the other hand, higher capabilities would increase the cost of the device. Hence, under prescribed cost constraints, increasing the number of high-cost devices may reduce a large number of low-capacity devices, which would affect sensing coverage performance such as sensor node density, coverage degree, or coverage area.

An optimal heterogeneous deployment can achieve lifetime sensing coverage by several times as much as that with homogeneous deployment. [8]

Coverage and connectivity depends on sensors. Coverage is used to check if the area which is of interest to the application, is covered or not properly. If the area of interest is no more covered then we say that the network lifetime is decreasing [9]. WSNs achieve better balance between cost of sensors and performance if degree of heterogeneity is involved into the network by placing high-end and low-end sensors which having different sensing capabilities [10].

5.2. Security

A WSN is vulnerable to different types of attacks or threats and risks [11] due to the nature of the transmission medium, remote and hostile deployment location, and the lack of physical security in each node. An adversary can compromise a sensor node, alter the integrity of the data, eavesdrop on messages, inject fake messages, and waste network resource.

Main obstacle in security of WSN is Limited resources like

a. Limited memory and storage space – Sensor devices only have a limited capacity for storing code and cryptographic keys. An effective security mechanism must limit the size of keys and code for the security algorithm.
b. Limited processing capacity – Sensors and gateways (to a lesser extent) have very limited, or no capacity to perform the processing required by cryptographic functions.
c. Limited power – Once sensors (and gateways) are deployed, they cannot be easily replaced or recharged.

From above security discussion it is clear that computing power, storage, and battery power, collectively as security capacity. In general, the higher the security capacity, the better equipped the device in the WSN is for incorporating security.

In heterogeneous sensor networks where there is a combination of high-end sensors having more memory, more computational power and more energy along with low-end sensors having less capabilities, so that limited resources problem can be easily solved by using heterogeneity in WSN.

5.3. Data Aggregation

Data aggregation reduces communication cost and increase reliability of data transfer [11]. Data aggregation is necessary for WSN applications because when large amount of data to send across the network there is problem data redundancy. In data aggregation data is collected from multiple sensors and combined together to transmit to the base station.

In this case, aggregated data is more important than individual readings. This method is possible with cluster- based approach, For this approach communication between the nodes is necessary, and there is large consumption of energy of the total energy consumption of the WSNs for communication. In heterogeneous networks, some of the nodes are more powerful than the other ones nodes which is very useful for hierarchical routing protocol because it reduces the hardware cost of the network.

In hierarchical routing clusters are created, separate cluster head is assigned to each cluster. Responsibilities of cluster head, is to collect and aggregate data from their cluster members and transmit the aggregated data to the sink. Hence the energy consumption is reduced due to data aggregation because only small amount of data is transferred to the sink.

Single hop manner in clustering for data aggregation spends less time and energy. But if there is long distance between sensing node and sink, they require more energy. The alternative approach is multihopping. But in multi-hopping the nodes nearest to the cluster head have the highest energy loss due to relaying. As a result of it, non-uniform energy drainage pattern can occur in the network.

Our analysis shows that cluster-based solutions are best suited for heterogeneous dense networks, with limited dynamics.

6. DESIGN ISSUES OF HETEROGENEOUS ROUTING PROTOCOLS

Due to small amount of computing, radio and battery resources of sensors, while designing routing protocols for heterogeneous wireless sensor network following requirements need to be considered.

6.1. Network Dynamics

Sensor nodes sink and monitored events are three main components in sensor network. Some networks use mobile sensors [12]. So routing protocol should support mobility of sinks or cluster-heads (gateways). Routing messages to or from moving nodes is more challenging because route stability, energy and bandwidth are an important optimization factors. The sensed event can be dynamic or static which is depends on the application [13]. For example fire detection where static events generate traffic when reporting is required and target detection or tracking application where the event is dynamic which requires periodic reporting.

6.2. Node Deployment

Another issue is the topological deployment of nodes. It is application dependent and affects the performance of the routing protocol. Deployment is either deterministic or self-organizing. In deterministic method sensors are manually placed and data is travelled through pre-determined paths. In self-organizing sensor nodes are scattered randomly and creating route in an adhoc manner. Optimal clustering becomes a critical issue when the distribution of nodes is not uniform.

6.3. Energy Considerations

The process of setting up the routes during the data transmission is greatly influenced by energy considerations. Because the transmission power of a wireless radio is proportional to squared distance or even higher order in the presence of obstacles. In multihop routing there is significant overhead due to topology management and medium access control otherwise it consumes less energy. On the other hand direct routing would perform well enough if all the nodes were very close to the sink [14] but consume more memory.

6.4. Data Delivery Models

There are three data delivery models continuous, event-driven, and query-driven and hybrid [15] to the sink. Each sensor sends data periodically in continuous delivery model. On the other hand event-driven and query driven models sends data when an event occurs or a query is fired by the sink. Some networks use a hybrid model using a combination of above data delivery models. Minimization of energy consumption and route stability in routing protocol is highly influenced by the data delivery model. It has been concluded in [16] that habitat monitoring applications data is continuously transmitted to the sink so in such application hierarchical routing protocol is the most effective option and the reason is that such application generates large amount of redundant data. Using data aggregation on route to the sink, traffic and energy consumption can be reduced.

6.5. Node Capabilities

In previous works, all sensor nodes are, having the same capability in terms of communication, power and computation and such nodes are called homogenous nodes. But for real time deployment in current scenario some nodes with more energy to act as the center of data aggregation, processing, and transmission is required so that the energy dissipation of the whole network can be balanced.

In HWSN, the load of communication to the sink and aggregation is handled by these powerful nodes. Insertion of set of heterogeneous sensors raises multiple technical problems related to data routing. Some applications might require a mixture of sensors for monitoring pressure, humidity and temperature of the surrounding environments. These special sensors either deployed independently or the functionality can be incorporated in the normal sensors on demand. These sensors generate data at different rates, and hence different quality of service constraints and multiple data delivery models, as explained earlier are used. Therefore, such heterogeneous nodes make routing more challenging.

6.6. Data Aggregation

Data aggregation is the grouping of data received from different source node. Functions used for that are suppression, min, max and average [17]. Using this number of data transmission would be reduced from cluster to sink. It is recognized that energy required for computation would be less than energy required for communication. Hence this technique has been used to achieve better energy efficiency and traffic optimization in many routing protocols.

6.7. Resilience

Due to environment problem or battery consumption sometimes sensors, unpredictably stop working [18]. This problem can be overcome by discovery of the alternate path. Hence protocols and the algorithms for routing should be designed in such a way that which will deal with all the possibilities that can result to fault tolerance.

6.8. Scalability

When the hardware is put-on and system effectiveness is increased then system is said to scalable [19]. Routing methods must be suitable for huge collection of motes in WSNs and should be scalable enough to talk back to the events take place in the environment.

7. REVIEW OF ENERGY EFFICIENT HETEROGENEOUS ROUTING PROTOCOL BASED ON RESOURCE HETEROGENEITY

As we have discussed in Section 4, effective routing technique for heterogeneous network is hierarchical routing and suitable method for hierarchical routing is clustering based approach because it’s having many advantages as follows.

a. Reduces the size of the routing table by localizing the route setup
b. Conserves communication bandwidth
c. Prolonged battery life of individual sensor
d. No topology maintenance overhead
e. Reduce rate of energy consumption

7.1. Performance Measure of Clustering

To evaluate the performance of clustering protocols, some performance measures are used.

a. Network lifetime
   It’s a time interval from the start of the sensor network until the death of the first alive node.
b. Number of cluster heads per round:
   Number of normal nodes which would send information aggregated from their cluster members directly to the sink node.
c. Number of nodes per round
   Total number of nodes whose energy is not yet exhausted.
d. Throughput
   It’s a total rate of data sent over the network, which includes the rate of data sent from cluster heads to the sink node and the rate of data sent from the nodes to their cluster heads.

7.2. Classification of Clustering Attributes

Cluster properties are given as follows

a. Cluster Count
   In some of approaches CHs are predetermined based on resource heterogeneity [20], [21], thus, the number of clusters is preset. For some other approaches CH selected randomly hence yields variable number of clusters.
b. Intra-cluster Topology
   It's a multi-hop sensor-to-CH connectivity within cluster for communication.
c. Connectivity of CH to BS
   Using this CHs send the aggregated data to the BS with direct link or with multi-hop link.
d. Mobility of CH
   CH can be stationary or mobile. CHs can move within a limited region to reposition themselves for better network performance.
e. Node Type of CHs: Sensor nodes which having more resources like energy, computation power and communication resources are selected as CHs
f. Role of CH: CHs simply relaying the traffic and does the aggregation or fusion of the sensed data.

Then CH Selection Criteria is as follows:

a. Initial Energy when any algorithm starts it considers the high initial energy node as a CH.
b. Residual Energy After few of the rounds are completed, the cluster head selection should be based on the energy remaining in the sensors.
c. Energy Consumption Rate The energy consumption rate V_i (t) based on following formula $V_i(t) = [I_{initial} – E_{re}(t)] / p$
   Where $I_{initial}$ is the initial energy, $E_{re}(t)$ is the residual energy and p is the current round of CH selection.
d. Average Energy of the Network The average energy is used as the reference energy for each node that should own in current round to keep the network alive.

Clustering handles scalability and energy consumption challenge problem efficiently. Proposed algorithm for heterogeneity essentially focuses on three aspects.

7.3. Election of the Cluster Head by the Energy Prediction Scheme and Elimination of the nearest nodes to the base Station from the Election Process

Many methods have been proposed which are given in (SEP) (DEEC) (EDFCM) [22], [(REP)[23]] but as shown in [24] EEPCA(energy- efficient prediction clustering algorithm) [25] is best method therefore, the nodes with high residual energy and lesser communication cost are more likely to become a CH. An energy dissipation prediction model proposed for this algorithm is more energy efficient. This algorithm has two steps.

7.3.1. Calculation of the Distance between Nodes

Energy consumption of node x while transmitting a message to node y is defined as E_x^{tran} and node y received data strength with energy $E_{y,x}^{rec}$. If the distance is $d_{x,y}$ between node x and node y, then the relationship between both the energy E_x^{tran} and $E_{y,x}^{rec}$ shown in (1). C is a constant and θ is the distance-energy gradient that changes from (1) to (6) depending on the application environment.

$$\mathrm{E}_{y,x}^{rec} = \frac{C}{d_{x,y}^{\theta}} \times \mathrm{E}_x^{tran} \tag{1}$$

7.3.2. Cluster Head Selection

The nodes with more residual energy have higher probability to become a CH. In the next round it is the same for the other nodes to become a CH. To find out nodes probability to become the cluster head, the node residual energy must be found out. The probability pi of becoming a CH of every node is changing in every round according to its current residual energy. The authors first calculate the optimal number of cluster heads K_{opt}. N is the total number of nodes. The proportion is given in (2).

$$P_{opt} = \frac{K_{opt}}{N} \tag{2}$$

The average energy of the nodes within node x's communication range is given in (3)

$$w(E)_x = \frac{Ex_i}{\sum_{y=1}^{n} \left(E_y \big/ n \right)} \tag{3}$$

Where n is the number of nodes within node x's communication range.
To do accurate energy dissipation prediction, authors divided the communication rang of nodes into two sublevel then the average energy consumption of every round within every node's communication range is $E_{x\text{–}round}$ and the predicted energy consumption of every node in every round is E_{consume}, respectively. So the communication cost factor is calculated as given in (4)

$$w(C)_x = \frac{\bar{E}_{consume}}{\bar{E}_{x-round}} \tag{4}$$

After combining $w(E)_x$ and $w(C)_x$, the probability of node x to be elected as a cluster head is given in (5)

$$p_x = P_{opt} * (a w(E)_x + b w(C)_x) \tag{5}$$

Where a+b=1. Here a and b will be set to 0.5
A new threshold $T(x)$ for node x is similar to LEACH protocol, as shown in the (6)

$$T(x) = \begin{cases} \dfrac{p_x}{1 - p_x\left(r \bmod \left(1 \big/ p_x \right) \right)} \\ \times \begin{bmatrix} (a w(E)_x + b w(C)_x) \\ + r_s div\left(\dfrac{1}{p_x} \right) \\ \times (1 - a w(E)_x + b w(C)_x) \\ \end{bmatrix} \\ 0, \end{cases} \tag{6}$$

where r_s is the number of rounds that a node fails to be selected as the cluster head.

7.3.3. Energy Consumption Prediction Mechanism

As each node keeps appropriate information of all the nodes within communication range and their mutual distance. For example any node within communication range of node j can calculate the energy consumption of node j in r-1 round. According to the current energy of node j and the actual energy consumed in r-1 round that is the residual energy of node j can be predicted at the beginning of r round as given in (7).

$$E_{j_{r\_prediction}} = E_{j_{r-1}} - E_{j_{r-1\_consume}} \tag{7}$$

Based on this prediction value cluster head is elected and also it reduces the energy, required for broadcasting energy information.

Furthermore nearest nodes to the base station consume more energy because each member node communicates with cluster head and not with the base station. So need to eliminate such nodes from cluster process. In [26] author proposed new method to optimize this energy which based on the firefly algorithm. This approach allows the boundary of the excluded nodes efficiently

7.2. Saving Energy Consumption by Multihop between Cluster Head and Sink Node

As earlier research suggests that multihop hierarchical routing saves more energy than single hop routing. In [27] HEED, CHs near the sink consume more energy very quickly than others and they would die first, which causes the energy hole around the sink. In EHEED, drawback of HEED is removed by using multihop path to the sink with the help of relay node.

In [28], author proposed a stable election clustering protocol called energy-efficient heterogeneous clustered (EEHC) scheme in the heterogeneous model. The nodes in the network are divided into three categories, the normal nodes, the advanced nodes, and the super nodes according to their initial energy. Actually, the normal nodes have the least energy, the advanced nodes have more energy than the normal ones, and the super nodes have the highest level of energy. EEHC is based on SEP, and the three types of nodes in EEHC have their own election probability to be CHs within a fixed time to keep stable. In improved EEHC further and proposed a multihop clustering protocol called MCR [16]. To reduce the energy consumption, the multihop path is built in MCR. Steps of MCR are as follows.

7.2.1. The CH Election Weighted Probabilities

Both single-hop and multihop transmission is used in protocol MCR. CHs are selected based on the same weighted probability formulas which are used in EEHC. Nodes in Cluster communicate with the CH by using single-hop communication and CH communicates with the sink through multihop communication by choosing the proper CH nearest to the sink as the next hop. In MCR, advanced nodes, super nodes and normal nodes, are deployed randomly in the sensing area to create the HWSN. The initial energy of advanced nodes is more than the normal nodes, and initial energy the super nodes is more than the advanced nodes. The authors consider that m_0 percentage of m nodes are super nodes which initially have β times more initial energy than the normal nodes and the n* m*(1- m) fraction of total nodes are advanced nodes which initially have α times more initial energy than the normal nodes, and the remaining (1- m) percentage of total nodes is normal nodes. n is the number of total sensor nodes. E0 is defined as the initial energy of the normal node then, initial energy of each super node and each advanced node should be E0(1+ β) and E0(1+α), respectively. The weighted probabilities of three kinds of nodes to become CHs are as given in (8), (9), (10).

$$\mathrm{P}_{normal} = \frac{\mathrm{P}_{opt}}{1 + m(\alpha - m_0(\alpha - \beta))} \tag{8}$$

$$\mathrm{P}_{advanced} = \frac{\mathrm{P}_{opt}}{1 + m(\alpha - m_0(\alpha - \beta))} \times (1 + \alpha) \tag{9}$$

$$\mathrm{P}_{\mathrm{super}=} \frac{\mathrm{P}_{opt}}{1 + m(\alpha - m_0(\alpha - \beta))} \times (1 + \beta) \tag{10}$$

Threshold to elect the CHs for normal nodes, advanced nodes, and super nodes can get by the above formulas, respectively.

7.2.2. Cluster Formation, Route Selection, and Data Transmission

In cluster formation phase, non-CH nodes join the nearest CH simply by detecting the RSSI that depends on the received signal from the CHs. After the cluster formation a TDMA slot is required for every cluster, and every CH node sends the TDMA slot to its member nodes to tell them when they can transmit the data. In route selection phase, a CH aggregates the data from the member nodes of cluster and then transmits the data to the sink node over a multihop path. Since the shortest path will have the lowest energy cost, a CH node chooses another CH node as the next hop whose distance to sink is the shortest one. In the data transmission phase, a CH node collects and aggregates the data from its member nodes in the fixed TDMA slot. After this, the CH transmits the data to the sink over the previously built multihop path in the route selection phase.

Furthermore in [29] author given multihop routing with shortest path, also avoids the routing loop. While route building process basestation broadcasts Hello packet and one hop nodes receiving it, and they will append its cluster id and rebroadcast the Hello packet. Also node remembers the short path to the base station node by viewing the path in the Hello Packet. This will avoid the routing loop.

7.3. Evolutionary Algorithms

An evolutionary algorithm (EA) is a subset of evolutionary computation. Biological evolution is a motivation for mechanism used in EA such as reproduction, mutation, recombination and selection The EAs are used to prolong lifetime of network and optimize energy consumption with heterogeneity for handling the cluster based problem, such as EAERP, ERP [30], and SAERP [31]. The evolutionary-based routing protocol EAERP redesigned some important features of EAs, which can guarantee longer stable period and extend the lifetime with efficient energy dissipation.

SAERP combined the main idea of SEP and EAs, and SAERP mainly intended to increase the stability of the network. So these routing schemes which are inspired genetically demonstrated their advantages in prolonging the lifetime of HWSNs.

The key idea of SAERP is to insert energy-aware heuristics for both population initialization and mutation operator while constructing an appropriate fitness function for approaching robust performance

In SAERP Let I = (I1, . . . , IN) denote the encoding of a clustered WSN with N sensors, where $I_i \in \{0, 1, -1\}$. Inactive, non-CH, and CH sensors are denoted by codes −1, 0, and 1 respectively. To initialize a population of n individual solutions given in (11).

$$\forall i \in \{1,\ldots,N\} \text{ And } \quad \forall j \in \{1,\ldots,n\}$$

$$\mathrm{I}_i^j = \begin{cases} 1 \; if \; \mathrm{E}(sensor_i) \geq \mathrm{E}_{avg}(r) \wedge rand \leq p \\ 0 \; if \; \mathrm{E}(sensor_i) \langle \; \mathrm{E}_{avg}(r) \vee rand \rangle \, p \\ -1 \; if \; \mathrm{E}(sensor_i) = 0 \end{cases} \tag{11}$$

where p is the desired percentage of the CHs, rand is a uniform random number, E_{avg} is the average energy of the sensors in the current round r, and E($sensor_i$) is the residual energy of sensor i. This representation implicitly facilitates the formation of a dynamic number of CHs during the single and throughout the whole rounds of the routing protocol. Fitness function which numerically quantifies how good that individual is a solution to the routing optimization problem. For SAERP, the proposed objective function is defined as the minimization of the total dissipated energy in the network, measured as the sum of the total energy dissipated from the non-CHs to send data signals to their CHs, and the total energy spent by CH nodes to aggregate the data signals and send the aggregated signals to the base station. The next component of the proposed EA is the selection operator. It selects partners using binary tournament selection from the current population and transfers them to the mating pool for reproduction. Recombination and mutation are the perturbation operators, which can alter the routing solutions found in the population.

In each round of the routing protocol, the cluster formation phase generates an initial population of solutions, the fitness of which is then evaluated and based on the fitness values, the parents are selected to generate a new population via recombination and mutation operators. This process is repeated until the termination condition of the evolutionary algorithm occurs. SAERP performs better than both LEACH and SEP in providing maximum stability and minimum instability periods for both homogeneous/heterogeneous WSNs.

Furthermore the approach given in [32] combines the fuzzy c-means clustering and neural network to make the proposed algorithm more energy efficient. To form an equal size cluster author used FCM algorithm and decision of selection of cluster head is made using neural network where input factors are distance from basestation, heterogeneity and energy of the node .

8. CONCLUSION

This paper presents in–depth design issues of routing in heterogeneous wireless sensor network. There are severe constraints in wireless sensor network, like lifetime, computation etc. Many researchers' are working in this domain to evolve a technique which can increase the overall lifetime of the system. As per the survey done here, if heterogeneous nodes are taken on account and the appropriate scheme is taken for the sleep - awake and data transfer, then it will definitely have a huge impact on overall lifetime of WSN as compared to homogeneous system. As mentioned in this paper, these heterogeneous cluster based routing protocol have ability to balance energy consumption of the nodes in the whole network and multihop path from cluster head to sink is a very important concern to save energy during data transmission. Through the study, it is deduced that the optimal way of heterogeneity with respect to extending lifetime of the network, is to have node battery heterogeneity, rather than of link or computational heterogeneity. This survey will help the future researchers to design energy efficient routing algorithm for heterogeneous wireless sensor network.

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